EXHIBIT 12

CONFIDENTIAL EXHIBIT

EXHIBIT 13

United States Patent [19]

Poole

[11] **4,166,280**

[45] **Aug. 28, 1979**

[54] **HIGH PERFORMANCE TELEVISION COLOR CAMERA EMPLOYING A CAMERA TUBE AND SOLID STATE SENSORS**

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[73] Assignee: **Ampex Corporation**, Redwood City, Calif.

[21] Appl. No.: **848,482**

[22] Filed: **Nov. 4, 1977**

[51] **Int. Cl.**[2] **H04N 9/04**; H04N 9/07; H04N 9/09

[52] **U.S. Cl.** **358/51**; 358/43; 358/50; 358/52; 358/41

[58] **Field of Search** 358/43, 50–52, 358/41, 213, 55, 44; 315/370, 371

[56] **References Cited**

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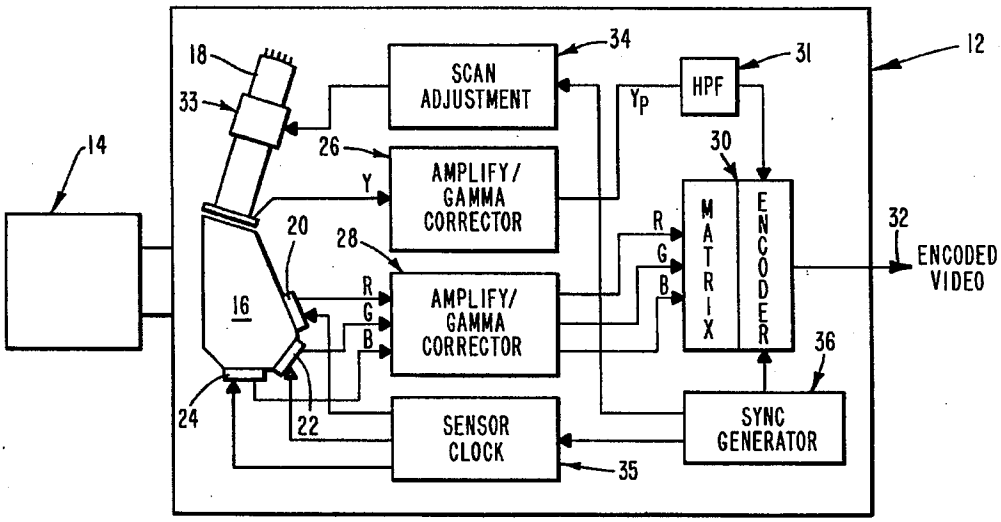
Primary Examiner—John C. Martin

Attorney, Agent, or Firm—Robert G. Clay; George B. Almeida

[57] **ABSTRACT**

A conventional, high resolution camera pickup tube is employed to generate the luminance signal corresponding to the greater bandwidth luminance component of a composite video signal. At least one low resolution, solid state sensor is combined with the tube to generate the red, green and blue color signals corresponding to the lower bandwidth red, green and blue color components of the video signal. A scan adjustment circuit precisely conforms the tube scan raster with the near-perfect geometry of the solid state sensor array. A clocking circuit synchronizes the scan rate of the sensors with that of the pickup tube. Gamma correction, matrixing and encoding are provided via video processor circuitry to generate the broadcast quality, composite video output.

19 Claims, 22 Drawing Figures



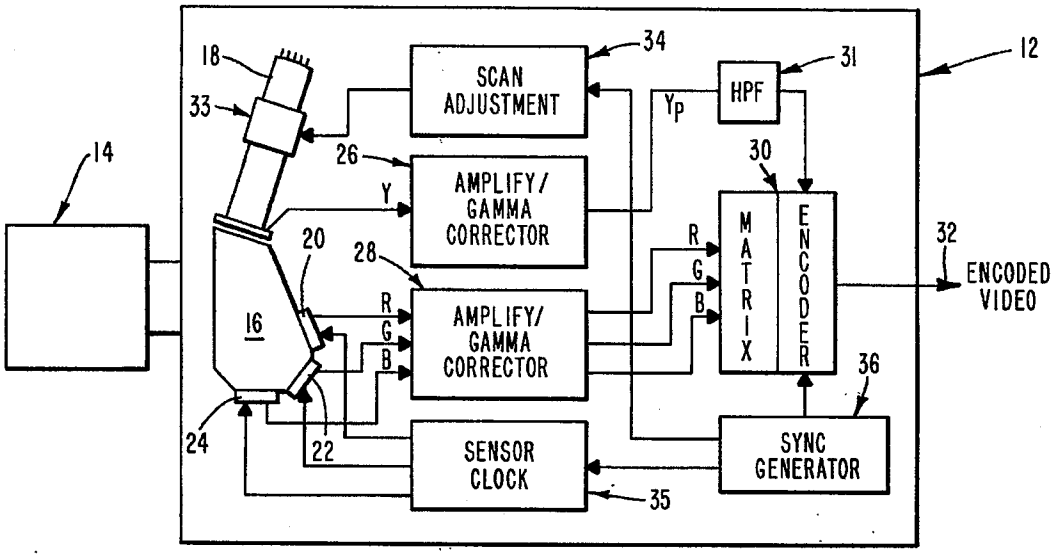
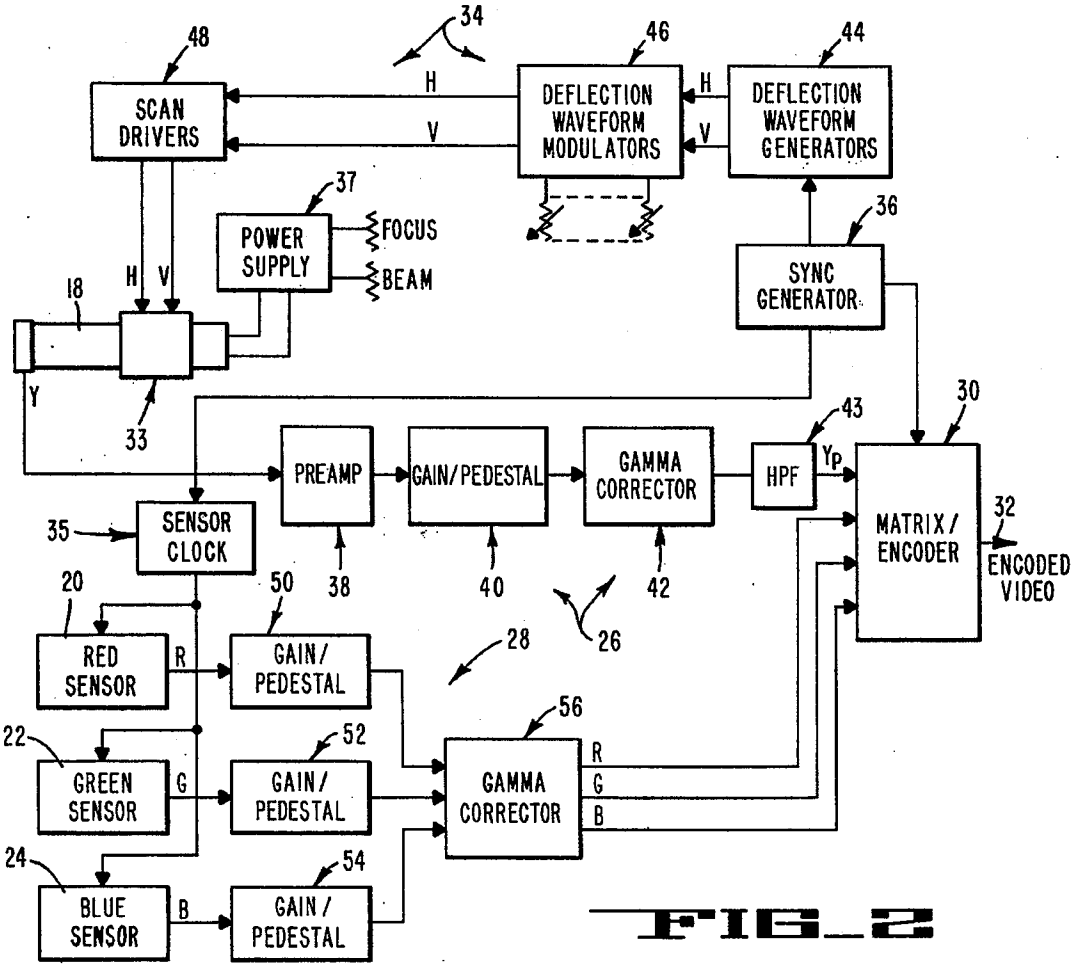

SCAN ADJUSTMENT
HPF
AMPLIFY/ GAMMA CORRECTOR
AMPLIFY/ GAMMA CORRECTOR
MATRIX
ENCODER
SENSOR CLOCK
SYNC GENERATOR
ENCODED VIDEO
12
14
16
18
20
22
24
26
28
30
31
32
33
34
35
36

FIG_1


SCAN DRIVERS
DEFLECTION WAVEFORM MODULATORS
DEFLECTION WAVEFORM GENERATORS
POWER SUPPLY
FOCUS
BEAM
SYNC GENERATOR
PREAMP
GAIN/PEDESTAL
GAMMA CORRECTOR
HPF
MATRIX/ ENCODER
ENCODED VIDEO
SENSOR CLOCK
RED SENSOR
GREEN SENSOR
BLUE SENSOR
GAIN/ PEDESTAL
GAIN/ PEDESTAL
GAIN/ PEDESTAL
GAMMA CORRECTOR
18
20
22
24
26
28
30
32
33
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35
36
37
38
40
42
43
44
46
48
50
52
54
56

FIG_2

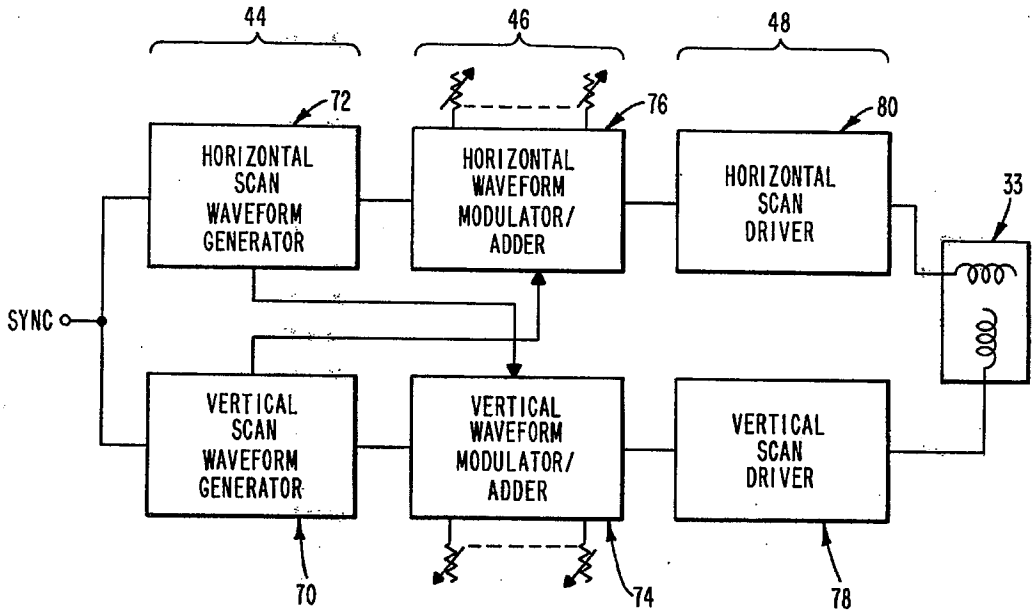
44
46
48
72
76
80
HORIZONTAL SCAN WAVEFORM GENERATOR
HORIZONTAL WAVEFORM MODULATOR/ ADDER
HORIZONTAL SCAN DRIVER
33
SYNC
VERTICAL SCAN WAVEFORM GENERATOR
VERTICAL WAVEFORM MODULATOR/ ADDER
VERTICAL SCAN DRIVER
70
74
78

FIG_3

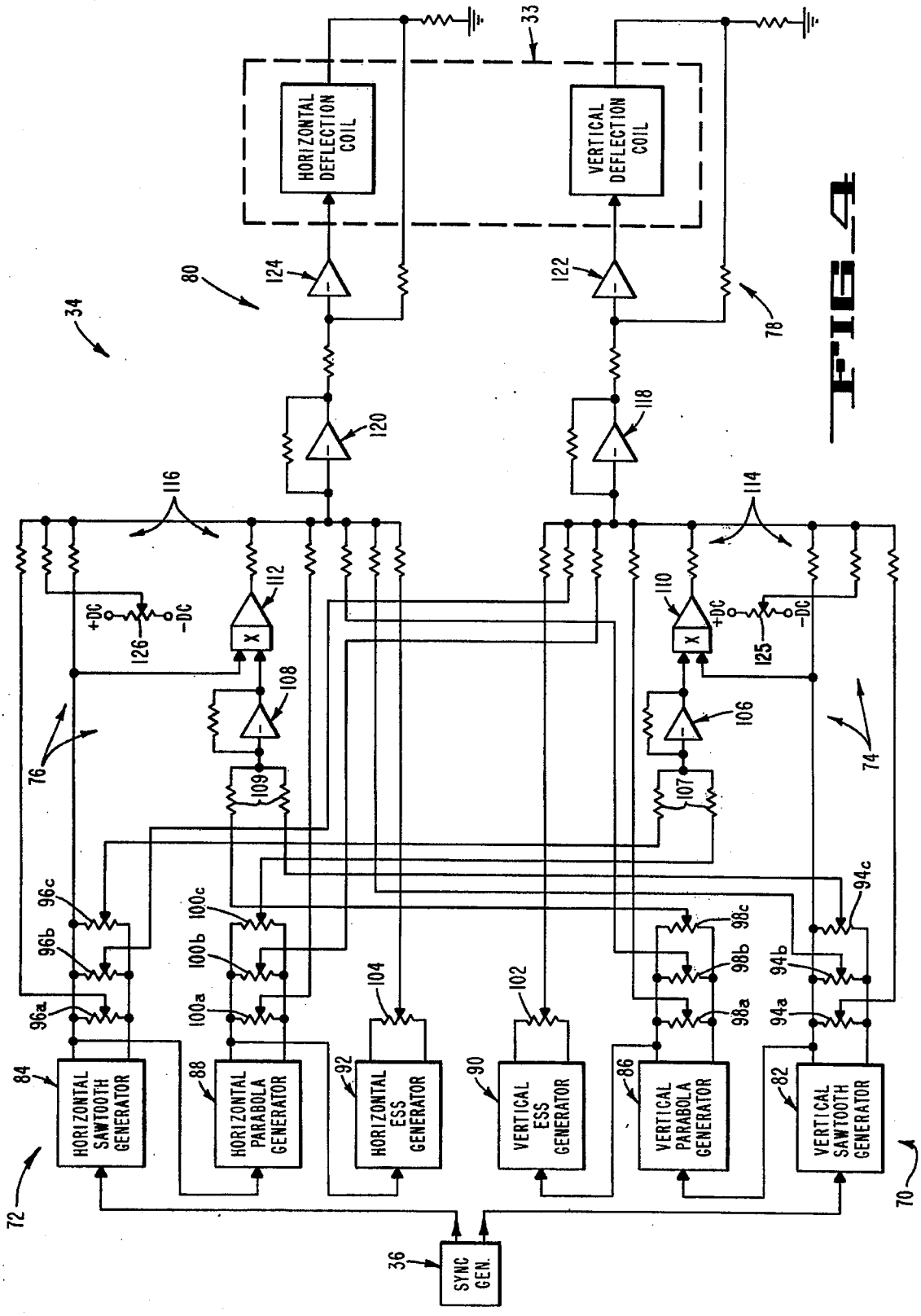
HORIZONTAL DEFLECTION COIL
VERTICAL DEFLECTION COIL
HORIZONTAL SAWTOOTH GENERATOR
HORIZONTAL PARABOLA GENERATOR
HORIZONTAL ESS GENERATOR
VERTICAL ESS GENERATOR
VERTICAL PARABOLA GENERATOR
VERTICAL SAWTOOTH GENERATOR
SYNC GEN.
+DC
-DC
33
34
36
70
72
74
76
78
80
82
84
86
88
90
92
94a
94b
94c
96a
96b
96c
98a
98b
98c
100a
100b
100c
102
104
106
107
108
109
110
112
114
116
118
120
122
124
125
126

FIG 4

COLUMN 1 NAME OF FUNCTION	COLUMN 2 METHOD OF GENERATION	COLUMN 3 SCAN WAVEFORM	COLUMN 4 PATTERN SCANNED ON TARGET OF TUBE	COLUMN 5 EFFECT ON LINEARITY CHART REPRODUCED ON MONITOR
VERTICAL CENTERING	ADD DC TO VERTICAL SCAN	60 Hz		
HORIZONTAL CENTERING	ADD DC TO HORIZONTAL SCAN	15kHz		
HEIGHT	ADD VERTICAL RAMP TO VERTICAL SCAN	60 Hz		
WIDTH	ADD HORIZONTAL RAMP TO HORIZONTAL SCAN	15kHz		
VERTICAL SKEW	ADD HORIZONTAL RAMP TO VERTICAL SCAN	60Hz		
HORIZONTAL SKEW	ADD VERTICAL RAMP TO HORIZONTAL SCAN	60 Hz		
VERTICAL LINEARITY	ADD VERTICAL PARABOLA TO VERTICAL SCAN	60 Hz		
HORIZONTAL LINEARITY	ADD HORIZONTAL PARABOLA TO HORIZONTAL SCAN	15K Hz		

FIG_5A

FIG_5B

FIG_5C

FIG_5D

FIG_5E

FIG_5F

FIG_5G

FIG_5H

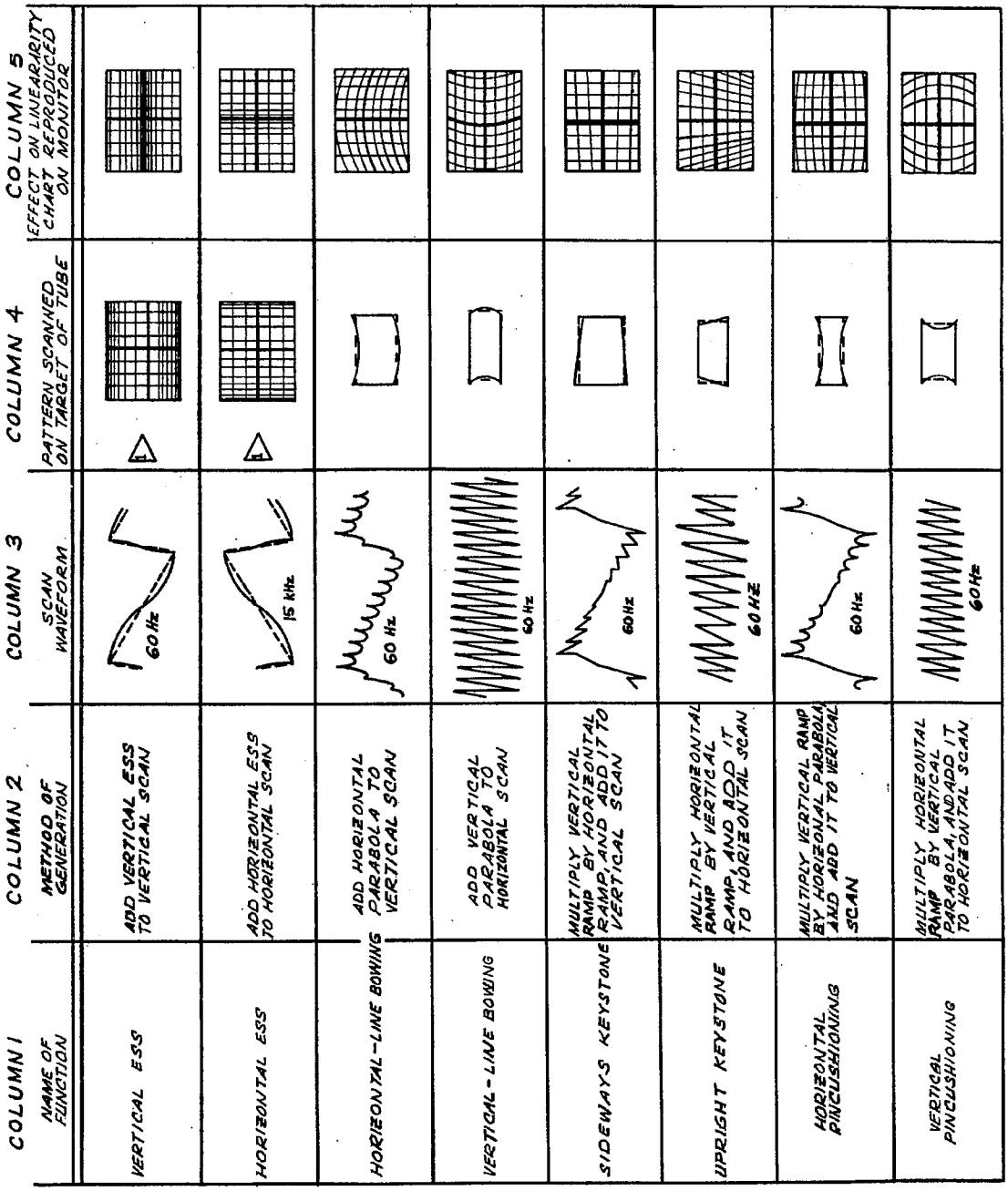

FIG_6A

FIG_6B

FIG_6C

FIG_6D

FIG_6E

FIG_6F

FIG_6G

FIG_6H

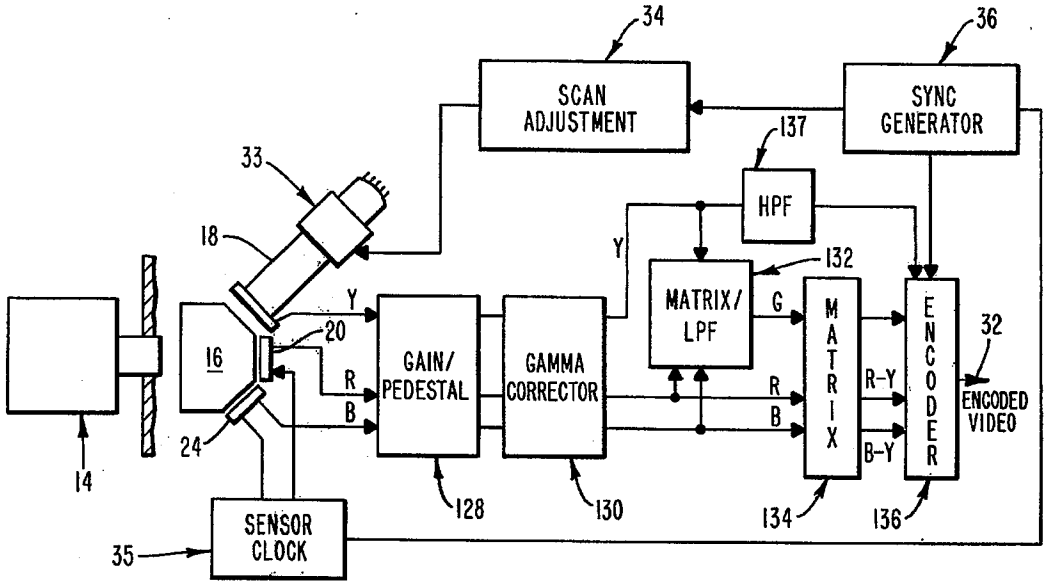
34
SCAN ADJUSTMENT
36
SYNC GENERATOR
137
HPF
33
18
Y
132
MATRIX/ LPF
G
MATRIX
ENCODER
32
ENCODED VIDEO
16
20
Y
R
B
GAIN/ PEDESTAL
GAMMA CORRECTOR
R
B
R-Y
B-Y
24
14
128
130
134
136
SENSOR CLOCK
35

FIG_7

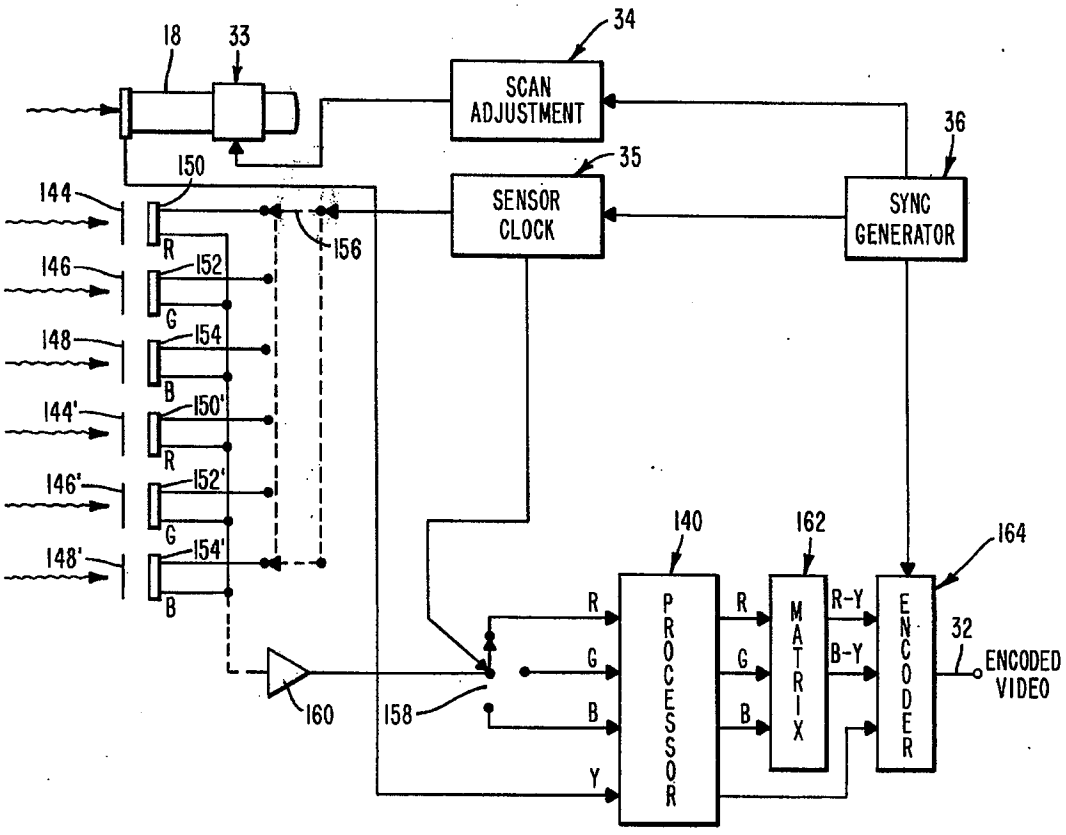
18
33
34
SCAN ADJUSTMENT
36
150
35
SENSOR CLOCK
SYNC GENERATOR
144
R
156
146
152
G
148
154
B
144'
150'
R
146'
152'
G
148'
154'
B
140
162
164
R
G
B
Y
PROCESSOR
MATRIX
ENCODER
R-Y
B-Y
32
ENCODED VIDEO
160
158

FIG_8

HIGH PERFORMANCE TELEVISION COLOR CAMERA EMPLOYING A CAMERA TUBE AND SOLID STATE SENSORS

BACKGROUND OF THE INVENTION

1. Field

The invention relates to television color cameras, and particularly to a hybrid color camera configuration employing a camera pickup tube in combination with a selected number of solid state sensors.

2. Prior Art

At present, practical color cameras can be classified into several basic types. A first type employs one or two camera tubes and color analysis is performed by a rotating disc containing red, green and blue, or red and blue, filters interposed between the camera optical lens and the camera tube. As the disc rotates, successive filters intercept the light directed to the tube target to generate signals corresponding to the red, blue (and green) color components of the scene. A typical camera is described in "New Two-Tube Color Cameras For Broadcast Use", B. M. Poole, Tech. Papers, NAB Eng. Conf., Mar. 23–26, 1969, pgs. 238–244.

In another type of camera, one tube is used and each point of the optical image is split into, for example, three color components by interposing an array of focused fine color filter stripes in the optical path. Each image point produces charged target areas corresponding to the color component points which are scanned by the tube electron beam, to generate a signal which sequentially describes the area charges. Electrical processing derives signals corresponding to the color components. Typical of such a one-tube camera is that described in the article "A Single Vidicon TV Camera System", Journal of the SMPTE, Vol. 79, April 1970, pgs. 326–330.

Other types of cameras employ two, three or four camera tubes, wherein the color components of the optical image are formed separately and the related signals generated continuously. The light from the camera lens is split into red, green and/or blue color components via dichroic mirrors, where each component forms an image on the camera tube target. Typical three and four tube cameras are described in; Ampex Corp. Catalog No. 1809173-01, "BC-230B, Manual of Theory of Operation", June 1975; Cohu Electronics, Inc., "Operating and Maintenance Instructions For 9800 Series Color Video Encoder", June 1970; RCA Catalog B.2000, "Transistorized Live Color Camera, Type TK-42", 1965; Sound and Vision Broadcasting, "A New Four-Tube Colour TV Camera", Vol. 7, No. 1, Spring 1966, pgs. 8–21.

In multiple tube cameras, the images formed on the targets must have correct spatial correspondence relative to each other to ensure that the color component pictures at the display are in register; i.e., spatially superimposed at all points. Consequently, the color analysis arrangements and the camera tubes must be very stable mechanically, and the scanning patterns traced on the tube targets must be as stable and identical as possible.

In any camera, the characteristics of a camera tube that relates output signal and scene brightness together with that of any gamma corrector used, must be such that over a large range of scene brightness, an approximately linear relationship exists between a change of scene brightness and the corresponding change at the display. Therefore, in a camera incorporating several tubes (and several gamma correctors), the combined characteristics of one tube and its associated corrector must be well matched to the others. Thus the deflection assemblies for the pickup tubes are first computer-matched to provide yoke and tube combinations of similar characteristics, and thus scan raster geometries which are as similar as possible. In addition, one tube (for example, the green-channel tube) may be selected as a master tube/channel, and various analog-waveform driving signals are applied via suitable electronics to match the scan rasters of the remaining slave tube, or tubes, of corresponding slave channels, with the master tube raster, as generally described in the multiple tube references of previous mention.

None of the above techniques are capable of providing the degree of accuracy required to cause a pickup tube to generate a scan raster with the near perfect physical geometry of a solid state image sensor. In addition, most of the multiple tube cameras are bulky and heavy, require skilled operation, while lacking sensitivity and economy of operation.

Recent developments in the state-of-the-art of solid-state sensors have spurred interest in their use in relatively low resolution electronic news gathering (ENG) color cameras in place of the conventional Plumbicon, Vidicon, Saticon, etc., pickup tubes. By way of example, typical ENG color cameras employing solid state sensors are described in; "All-Solid-State Camera for the 525-Line Television Format", IEEE Transactions on Electron Devices, Vol. ED-23, No. 2 February 1976, pgs. 183–189; "Solid State Image Sensors: Improvements in Signal Processing Techniques", BBC Research Dept., Report BBC RD 1976/4, January 1976; RCA Brochure on the SID 51232, printed Jan. 1975. However, a typical broadcast quality television color camera system requires a luminance component of 4.2 megaHertz bandwidth or better. This parameter imposes the requirement that a solid state array have a geometric configuration of the order of 600×488 photosensitive elements. However, the geometry of presently available state-of-the-art solid state sensor arrays, and those in the foreseeable future, provide only on the order of 320 by 244 photosensitive elements. Typical thereof, a photosensitive element of one type of such an array may contain 2 MOS transistors, 2 capacitors and 2 reverse biased photo diodes, whereby it is very difficult to accurately manufacture arrays with the greater number of elements required for broadcast quality color television use. It is estimated that several years development time is needed before the advent of such high resolution solid state sensors. Thus, the development of an RGB color camera of broadcast quality utilizing solid state devices alone is improbable in the immediate future.

However, an array with as few as 188 by 244 elements offers sufficient resolution to allow generation of the red, green and blue chroma signals, or of the R-Y and B-Y color components, since the chroma signals require on the order of 1 megaHertz bandwidth, or less. Accordingly, the specific combination of a pickup tube with presently available solid state sensors having a relatively small number of photosensitive elements, allows the development of a light weight, broadcast quality color camera of improved configuration.

When utilizing a pickup tube with solid state sensor devices, problems in registration arise due to the difference between the near perfect array geometry of the

accurately manufactured solid state devices and the relatively inaccurate scan raster of the tube, which cause, in turn, loss of resolution, color edge effects, etc. Thus, means must be provided to correct the tube scan raster to precisely conform same to the near perfect array geometry of the solid state sensors. This presents a different problem than that of prior art multiple-tube cameras as, for example, the four tube camera, wherein the various tube scan rasters need only be matched to each other, not made to conform to near-perfect array geometry.

SUMMARY OF THE INVENTION

The invention encompasses a hybrid, broadcast quality color camera employing a single high resolution camera pickup tube in combination with one or more presently-available low resolution solid state sensors. The arrangement provides the advantages of lighter weight, self-registration of the solid state sensors which require only mechanical alignment, equal-resolution response, equal gamma and equal bandwidth to eliminate color fringing and edge effects, and improved sensitivity and signal-to-noise advantages, particularly in the event the single vacuum pickup tube includes image intensification.

To this end, the invention contemplates a single Plumbicon, Saticon, etc., camera pickup to provide the high resolution luminance signal, in combination with one or more solid state sensors which provide a selected form of the low resolution red, green and blue color signals. The output from the tube's preamplifier is coupled to an associated video processor including gain, pedestal and gamma correction circuits, which generates a selected form of the luminance (Y) signal. The solid state sensor or sensors also are coupled to an associated video processor which includes gain, pedestal and gamma correction circuits. The luminance and chrominance signals are introduced to a matrix/encoder circuit which provides the broadcast quality encoded composite video signal.

A clock circuit is coupled to the sensor, or sensors, and provides clocking pulses to match the scan rates of the one or more sensors with that of the tube. A scan adjustment circuit is coupled to the deflection coils of the pickup tube, and provide the luminance channel with highly-sophisticated scan correction electronics for correcting the various raster inaccuracies inherent in the tube/yoke combination. More particularly, the adjustment circuit directs the tube scanning means to generate a near-perfect scan raster geometry to accordingly provide the precise registration required between the tube scan raster and the near-perfect geometry of the solid state sensors. The use of precise analog correction waveforms generated via the scan adjustment circuit to direct the tube scanning means to generate a near-perfect scan raster geometry, allows the combination of a tube and one or more solid state sensors to define a hybrid video color camera of broadcast quality.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a block diagram exemplifying one combination of a hybrid color camera employing three solid state sensors.

FIG. **2** is a block diagram exemplifying the system, and particularly the circuity of FIG. **1**, in greater detail.

FIG. **3** is a block diagram exemplying the scan adjustment circuit of the system of FIGS. **1**, **2**, which directs the generation of a near perfect scan raster geometry for the tube.

FIG. **4** is a schematic diagram depicting in greater detail the scan adjustment circuit of FIG. **3**.

FIGS. **5A–5H** are pictorial representations of inherent raster scan inaccuracies in a camera pickup tube, of typical low order scan adjusting waveforms applied to the tube deflection coils to correct such scan inaccuracies, and of the resulting corrected raster scan of cathode ray tubes in prior art systems.

FIGS. **6A–6H** are pictorial representations similar to those of FIGS. **5A–5H**, but depicting further raster scan inaccuracies, and the more sophisticated, high order, scan adjusting waveforms applied to the camera pickup tube deflection coils in accordance with the invention combination, and further showing the more precisely corrected scan raster which, in turn, provides the near-perfect tube scan geometry.

FIG. **7** is a block diagram of an alternative embodiment of the invention combination of FIGS. **1** and **2**, employing a pickup tube and two solid state sensors.

FIG. **8** is a block diagram of yet another embodiment, employing a pickup tube and one solid state sensor.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to FIG. **1**, a hybrid camera housing **12** includes a suitable lens **14** and, by way of example only, a (four-way) beam splitter prism **16** for separating the luminance (Y), and the red (R), green (G) and blue (B) colors. A camera pickup tube **18** is disposed against the prism to receive the luminance, and a plurality of solid state image sensors **20**, **22** and **24** of near-perfect array geometry are disposed against the prism to receive the red, green and blue color images, respectively. The Y signal generated by the target of the pickup tube **18** is introduced to an amplify/gamma corrector means **26**, while the R, G, B signals are introduced to an amplify/-gamma corrector means **28**. The resulting photopic luminance signal (Y_P) is introduced to an encoder portion of matrix/encoder means **30** via a high pass filter **31**, and the processed chrominance signals, R, G, B are introduced to a matrix portion of the matrix/encoder means **30**. The encoder portion of the means **30** in turn generates an encoded composite video output signal on line **32**. A scan adjustment means **34** is coupled to the deflection coils of the yoke **33** of the pickup tube **18** and corrects the scan raster thereof to cause it to conform to a near-perfect geometry such as that inherent in the solid state sensors **20**, **22**, **24**. A solid-state-sensor clock circuit **35** is coupled to the sensors **20**, **22**, **24** and provides scan timing at a selected scan rate commensurate with the scan rate of the pickup tube **18**. The timing for the camera system is provided via a sync generator **36** coupled to the clock circuit **35**, to the scan adjustment means **34**, and to the matrix/encoder means **30**.

In FIG. **2**, wherein like components of FIG. **1** are similarly numbered, the pickup tube **18** is coupled to a suitable power supply **37**, and to the scan adjustment means **34**, herein further shown as deflection waveform generator means **44**, deflection waveform modulator means **46**, and scan driver means **48**. The luminance signal Y is introduced to a preamplifier means **38** of the amplify/gamma corrector means **26** of previous mention. The means **26** further includes a gain/pedestal circuit **40** coupled to the preamplifier **38**, a gamma corrector circuit **42** coupled to the circuit **40**, and an (optional) high pass filter **43** coupled to the gamma circuit

42. The high pass filter 43 may be inserted to reduce the Livingstone color error as per common practice. The resulting processed photopic luminance signal Y_P is supplied to the matrix/encoder means 30.

The horizontal (H) and vertical (V) coils (not shown) of the yoke 33 of the pickup tube 18 are coupled to the scan driver means 48 of the scan adjustment means 34, which drivers in turn are supplied via the modulator means 46 with various superimposed H and superimposed V scan waveforms generated by separate H and V deflection waveform generators within generator means 44. The separate superimposed H and V waveforms are applied to the tube 18 as composite H and composite V scan correction waveforms which direct the tube scanning beam to generate a near-perfect scan raster geometry, whereby the tube scan raster may conform to the near-perfect geometry of the soild state image sensors 20, 22, 24 in accordance with the invention.

The solid state image sensors 20, 22, 24 are coupled to the clock circuit 35, which is coupled to the sync generator 36, wherein the combination supplies the scan timing signals for clocking the sensors at a selected scan rate commensurate with the scan rate of the pickup tube 18. By way of example, the tube scans at a rate of 15,750 scanning lines per second. Thus the clock circuit 35 supplies pulses which clock the sensors 20, 22, 24 with a clock pulse rate which is 15,750 pulses per second times the number of sensor elements in one (horizontal) row of sensors. Only the first clock pulse for each row is referenced to the start of each scanning line for the tube; hence the need to maintain perfect linearity and geometry with the tube and yoke assembly so that intermediate points scanned in the tube are coincident with those scanned in the sensor.

The sensors 20, 22, 24 in turn are coupled to respective gain/pedestal circuits 50, 52, 54 and thence to a gamma corrector circuit 56, wherein the circuits 50, 52, 54, 56 define the amplify/gamma corrector means 28 of FIG. 1. The RGB color signals are coupled to the matrix/encoder means 30 along with the photopic luminance signal from the gamma corrector circuit 42. Means 30 generates the encoded video color signal.

No further description is made herein of the processor, matrix and encoder circuits 38–42, 50–56 and 30, since these circuits are generally known in the art per se. Typical circuits 38–42 are shown in the Ampex Corp. Catalog No. 1809173-01, BC-230B of previous mention. Likewise, typical circuits 50–56 are shown in the BBC Research Dept. Series Manual and an example of the clock circuit 35 is shown in the RCA SID report, also of previous mention.

Although the block diagrams of FIGS. 1 and 2 depict a hybrid camera configuration having one tube and three solid state sensors; it is to be understood that various other combinations are contemplated within the invention concept; i.e., one or more solid state sensor devices and associated adjunct apparatus may be used to generate the related luminance and chrominance signals as further described, for example, with reference to FIGS. 7 and 8 below.

FIG. 3 depicts briefly the scan adjustment means 34 of FIGS. 1, 2 coupled to the yoke 33 of the pickup tube 18. V and H scan waveform generators 70, 72 are intercoupled to each of V and H waveform modulator/adder means 74, 76 in respective vertical and horizontal channels. The modulated/summed waveforms are fed from means 74, 76 to V and H scan drivers 78, 80 respectively. The latter two define the driver means 48 which drive the V and H deflection coils of the yoke 33 accordingly. The waveform generators 70, 72 provide the means (44) for generating various vertical and horizontal driving waveforms such as, for example, sawtooth, parabola and ess waveforms, of mirror image positive and negative phases. The modulator/adder means 74, 76 provides the deflection waveform modulator means 46 for superimposing various ones of the generated waveforms in the selected proportions and phases commensurate with the type and degree of scan correction required to correct raster inaccuracies for a specific pickup tube.

FIG. 4 exemplifies one schematic implementation of the scan adjustment means 34 of FIGS. 1–3. The camera sync generator 36 of FIG. 2 provides inter alia the conventional vertical and horizontal drive pulses to respective V and H channels of the scan adjustment means 34. The electronics in both channels are similar and include respective V and H sawtooth generators 82, 84, V and H parabola generators 86, 88 and V and H ess curve generators 90, 92. Each of the generators 82, 84, 86, 88, 90 and 92 provides two outputs, viz., positive and negative phase waveforms defining sawtooth, parabola and ess functions, wherein one phase is the mirror image of the other. The pair of outputs from sawtooth generators 82, 84 are coupled across respective multiple V and H potentiometers in parallel. In the vertical channel, the potentiometers comprise a V size adjust 94*a*, H skew adjust 94*b* and upright keystone adjust 94*c*, and in the horizontal channel an H size adjust 96*a*, V skew adjust 96*b* and sideways keystone adjust 96*c*. Likewise, the outputs from V and H parabola generators 86, 88 are coupled across respective multiple V and H potentiometers in parallel; i.e., in the vertical channel, V linearity adjust 98*a*, V line bowing adjust 98*b* and V pincushion adjust 98*c*, and in the horizontal channel, H linearity adjust 100*a*, H line bowing adjust 100*b* and H pincushion adjust 100*c*, respectively. The outputs from the ess generators 90, 92 are coupled across V ess adjust and H ess adjust potentiometers 102, 104 respectively. The positive phase outputs of the V and H sawtooth generators 82, 84 are fed to the V and H parabola generators 86, 88, and the positive phase outputs of the latter are, in turn, fed to the V and H ess generators 90, 92 respectively, The parabola generators 86, 88 are integrating circuits which perform one stage of integration on the sawtooth waveform to generate the parabola function. The ess generators 90, 92 are also integrating circuits which perform a second stage of integration, i.e., integrate the parabola function, to generate the ess function.

The H and V channels also include respective modulating waveform adder amplifiers 106, 108, sawtooth modulators 110, 112 and respective series of multiple summing resistors 114, 116. The amplifiers 106, 108 are inverting, operational amplifiers with a zero impedance summing junction, wherein the input to V amplifier 106 is coupled to the movable contacts of the sideways keystone and the H pincushion adjust potentiometers 96*c* and 100*c* via summing resistors 107. The H amplifier 108 input is coupled to the movable contacts of the upright keystone and the V pincushion adjust potentiometers 94*c*, 98*c* via summing resistors 109. The sawtooth modulators 110, 112 are linear four-quadrant multipliers, one input thereof being coupled to the respective amplifiers 106, 108, with the other inputs thereof being coupled to the positive phase outputs of the V and H sawtooth generators 82 and 84 respectively. The

outputs of the V and H sawtooth modulators **110, 112** are coupled to V and H scan waveform adder amplifiers **118, 120** respectively via summing resistors. Resistor series **114, 116** and the adder amplifiers **118, 120** together define the adder portion of the modulator/adder means **74, 76** of FIG. **3**. The adder amplifiers **106, 108** are required to sum the keystone and pincushion waveforms prior to their introduction to the sawtooth modulators **110, 112**. If a single waveform is fed to the modulators, the adder amplifiers **106, 108** may be omitted.

The V and H scanning voltage waveforms generated via the V and H adder amplifiers **118, 120** are fed to V and H scan driver amplifiers **122, 124** respectively, and thence to the V and H scan coils of the pickup tube yoke **33** as the separate, precisely corrected V and H deflection current waveforms. The latter provide the pickup tube **18** with the near perfect raster scan geometry in accordance with the invention.

The movable contacts of the V and H size adjust potentiometers **94***a*, **96***a* are coupled to the V and H adder amplifiers **118, 120** respectively via summing resistors in series **114, 116**. Likewise, the movable contacts of the V and H ess adjust potentiometers **102, 104**, and of the V and H linearity adjust potentiometers **98***a*, **100***a*, are coupled to the V and H adder amplifiers **118, 120** via respective summing resistors. The movable contacts of the V-line and H-line bowing adjust potentiometers **98***b*, **100***b* are coupled via summing resistors to the opposite channel (H and V) adder amplifiers **120, 118**, respectively. The movable contacts of the H and V skew adjust potentiometers **94***b*, **96***b*, which are in the V and H channels respectively, are coupled to the H and V adder amplifiers **120, 118** respectively via summing resistors. The positive phase outputs of the V and H sawtooth generators **82, 84** are also coupled via summing resistors to the adder amplifiers **118, 120** and provide the basic V and H sawtooth waveforms.

V and H centering adjust potentiometers **125, 126** have a DC voltage applied, and the movable contacts thereof are coupled via summing resistors to the adder amplifiers **118, 120** respectively.

The waveform generators **82, 84, 86, 88, 90** and **92** are not further described herein since they are generally known in the art per se, as shown for example in the BBC Engineering Training Manual, "Television Engineering, Principles and Practice", Vol. 3, 1957, Iliffe and Sons, Ltd., London.

Thus as shown by way of example only, eight correction waveforms are supplied by each of the V and H channels of electronics, and are selectively added to each other via the modulator/adder means **74, 76**, to supply the precisely corrected composite V and composite H deflection current waveforms to the tube yoke **33**. To this end, selected proportions and phases of the various correction waveforms are added to the basic vertical and horizontal sawtooth scan waveforms, as selected via the associated adjust potentiometers, to select the desired size and to correct for the various scan errors associated with camera pickup tubes known as centering, skewing, linearity, ess, line bowing, keystoning and pincushioning. These various scan errors and their various correction waveforms are individually shown and described with reference to FIGS. **5A–5H** and **6A–6H**, infra.

Accordingly, in operation, the sync generator **36** commonly used in video color cameras, herein supplies the vertical and horizontal drive pulses commensurate with vertical and horizontal flyback, for timing the correction waveform generation with the pickup tube vertical and horizontal active scanning intervals. In response to the sync generator **36**, the plurality of generators **82–92** generate two phases of vertical and two phases of horizontal sawtooths, two phases of V and two phases of H parabolas and two phases of V and two phases of H ess waveforms. The various outputs from the generators **82–92** are coupled across the potentiometers **94, 96, 98, 100, 102, 104** whereby select adjustment of the movable contacts thereof provides; a positive or a negative phase; a selected proportion of positve and negative phase amplitudes and thus a waveform of one or the other phase with reduced amplitude; or no output at all if the movable contacts are set in the middle since the mirror image phases cancel each other out. Thus the potentiometers allow the selection of any amount of either phase of any of the functions which are to be employed to correct for scan errors. In turn, the summing resistors **114, 116** and scan waveform adder amplifiers **118, 120** superimpose the amounts of the various waveforms selected via the adjust potentiometers for both the vertical and horizontal channels, to provide the corrected V and H drive waveforms for the tube.

FIGS. **5A–5H** and **6A–6H** depict various functions representing inaccuracies in the tube scan raster which require correction (column **1**), a brief statement of the method of correction as implemented electronically via the scan adjustment means **34** (column **2**), the scan waveform generated (column **3**), the pattern scanned on the pickup tube target (column **4**), and the effect of the correction applied as seen on a monitor (column **5**). FIGS. **5A–5H** depict various functions and associated correction waveforms known per se in prior art camera systems employing multiple pickup tubes. In the invention combination, the waveforms of FIGS. **5A–5H** as well as the more sophisticated waveforms of FIGS. **6A–6H** are applied to only the single pickup tube of the hybrid camera system to effect the required near-perfect scan raster.

As in all the potentiometers, adjusting the movable contact to the middle of its range provides a superimposition of equal magnitudes of the mirror image positive and negative phase outputs from the associated sawtooth, parabola or ess waveform generator, which thereby cancel each other. No output appears at the movable contact with such a potentiometer setting. As the movable contact is moved towards the positive output of the generator, correspondingly more of the positive output appears at the movable contact. Conversely, as the movable contact is moved towards the negative phase output of the generator, correspondingly more of the negative phase output appears at the center tap. At either extreme movable contact setting, the full magnitude of the positive or negative phase output generated by the particular generator appears at the potentiometer movable contact.

To exemplify the manner of making corrections, referring to FIG. **5C, 5D** together with FIG. **4**, the height and width (i.e., the vertical and horizontal size) of the scan raster may be varied by adding some vertical and/or horizontal ramp (or sawtooth) waveforms to the basic vertical and horizontal sawtooth scan waveforms. The terms ramp and sawtooth are herein generally interchangeable. Since the basic scan waveforms are themselves sawtooths, the addition of in-phase positive sawtooth waveforms as selected by the settings on the V and H size adjust potentiometers **94***a*, **96***a*, and as added together via the V and H adder amplifiers **118,**

120, provides larger amplitude V and H deflection current waveforms to the scan yoke 33, and thus a larger scan raster. On the other hand, if the V or H size adjust potentiometer 94*a*, 96*a* is adjusted to provide an out-of-phase negative sawtooth, the addition thereof with the basic V or H scan waveform respectively provides an associated degree of cancellation of the latter. This results in an actual V or H scan waveform which has a decreased amplitude relative to the amplitude of the basic scan waveform, and thus a scan raster of decreased height or width, respectively.

In FIG. 5A, 5B adjustment of the V and/or H centering adjust potentiometers 125, 126 provides an increasing and/or decreasing shift in the DC level of the basic V and/or H scan sawtooth waveforms (column 3) applied to the scan raster to shift the raster accordingly (columns 4, 5).

In FIGS. 5E, 5F adjustment of the H and/or V skew adjust potentiometers 94*b*, 96*b* respectively, results in adding a selected horizontal rate ramp to the basic V scan waveform (column 3) whereby an H ramp is superimposed on the V scan waveform, and a V ramp is superimposed on the H ramp waveform. This causes a corresponding vertical or horizontal parallelogram-shaped shift or distortion in the scan raster (columns 4, 5) to correct for V or H skew. The direction of V or H skew may be reversed by adjusting the associated skew adjust potentiometer to provide an amount of the opposite phase of ramp corresponding to the sense and magnitude of skew correction needed.

In FIGS. 5G, 5H adjustment of the V and/or H linearity adjust potentiometers 98*a*, 100*a* results in adding a vertical parabola to the basic V scan waveform, and/or a horizontal parabola to the basic H scan waveform, and/or a horizontal parabola to the basic H scan waveform (column 3). This provides a shift of the picture center with respect to its edges to correct for linearity errors in the scan raster (columns 4, 5).

The functions of FIGS. 6A–6H provides a further correction sophistication not generally required when matching the multiple tubes of prior art camera systems. Thus in FIG. 6A, 6B adjustment of the V and/or H ess adjust potentiometers 102, 104 provides a selected amount and phase of ess waveform which is added to the V and/or H scan waveform (column 3) via the V and/or H adder amplifiers 106, 108 respectively. This generates an ess correction waveform resembling a sinewave function which corrects for a sinewave type distortion in the scan raster (columns 4, 5). To this end, as shown in FIG. 6A, column 3, the addition of a positive phase of V ess to the basic V scan sawtooth is provided by moving the movable contact of the V ess adjust potentiometer 102 towards the positive phase output thereof an amount corresponding to the amplitude of positive phase V ess required to correct the existing V ess error. The raster is scanned with the horizontal lines closer together at the top and bottom portions of the raster, and further apart along the middle vertical portion of the raster (column 4). The opposite effect can be obtained by moving the movable contact towards the negative phase output of the V ess generator 90.

The H ess errors may be corrected by an analogous adjustment of the H ess adjust potentiometer 104, as depicted in FIG. 6B, wherein selected adjustment provides the specific amount and phase of ess waveform necessary to correct the error. In FIG. 6C, H line bowing errors are corrected by corresponding adjustment of the H line bowing adjust potentiometer 100*b* to provide the amount and phase of the H parabola necessary for addition to the basic V scan sawtooth waveform via the V adder amplifier 118. Column 3 depicts the resulting scan waveform generated by adding the H parabola to the V sawtooth via the adder amplifier 118, column 4 depicts the pattern scanned on the tube target, and column 5 the effect of the correction applied.

FIG. 6D depicts the analogous effects of adjusting the V line bowing adjust potentiometer 98*b* to provide the addition of a V parabola to the basic H scan sawtooth waveform. A resulting scan waveform is depicted in column 3, and the effects and correction thereof are depicted in column 4, 5.

In upright keystone correction, FIG. 6F, the upright keystone adjust potentiometer 94*c* is selectively adjusted to provide a desired amount and phase of V sawtooth (ramp) to the H modulating waveform adder amplifier 108, which is coupled to the H sawtooth modulator 112. It is assumed that the V pincushion adjust potentiometer 98*c* is set at the middle so there is no output from its movable contact. The modulator 112 also receives the basic H sawtooth waveform from the H sawtooth generator 84, whereby the H ramp is modulated by the V ramp from potentiometer 94*c*, which in effect comprises multiplying the H ramp by the V ramp. The resulting waveform is then added to the basic H scan waveform. When fed with a positive phase, the modulator 112 generates a multiplicative or modulating envelope where the amplitude of the H sawtooth is less at the beginning of the ramp and increases towards the end thereof (column 3). That is, the modulator 112 provides an H sawtooth envelope whose amplitude increases from beginning to end of the vertical scan interval. The resulting correction provides less horizontal deflection at the top of the scan raster, and progressively increased deflection as the scan proceeds down the raster.

If a negative phase of upright keystone adjust waveform is generated by suitable adjustment of the upright keystone adjust potentiometer 94*c*, then the width of the horizontal scan is larger at the top of the raster, and progressively decreases towards the bottom. As is true for any of the potentiometers, if the potentiometer 94*c* is adjusted to its center so that the mirror image phases cancel each other out, no waveform is generated, and no correction is made for upright keystone error.

The sideways keystone function, FIG. 6E, is provided by adjusting the sideways keystone adjust potentiometer 96*c*, which feeds H sawtooth (ramp) to the V modulating waveform adder amplifier 106. It is assumed that the H pincushion adjust potentiometer 100*c* is set at the middle so there is no output from its movable contact. The V ramp is modulated via modulator 110 by the H ramp from the potentiometer 96*c*, and then is added to the basic V scan waveform via the V adder amplifier 118 (column 3). The resulting sideways keystone correction is depicted in columns 4, 5.

Horizontal and vertical pincushion functions are depicted in FIGS. 6G, 6H. To adjust for V pincushion correction, FIG. 6H, assuming temporarily that the upright keystone adjust potentiometer 94*c* is set at the middle so that there is no output, the V pincushion adjust potentiometer 98*c* is adjusted to apply a selected amplitude of concave-down V pincushion parabola to the H modulating waveform adder amplifier 108. From the output of this inverting amplifier, the concave-up V pincushion parabola waveform is fed to the H sawtooth

modulator **112**, along with the basic H scan sawtooth waveform. The resulting H scan sawtooth is modulated by the V pincushion parabola to provide an envelope wherein the amplitude thereof is greater at the beginning and end of the vertical scan interval than at the middle of the interval (column **3**). This in turn makes the top and bottom portions of the raster progressively wider than the middle (columns **4, 5**).

If the other phase of V pincushion parabola is selected by commensurate adjustment of potentiometer **98***c*, the scan raster would have a progressively larger width along the middle portion than at the beginning and end of the vertical scan interval.

Likewise, in making the H pincushion correction, assume the sideways keystone adjust potentiometer is set at the middle, whereupon the H pincushion adjust potentiometer is adjusted to supply, via the V modulating waveform adder amplifier **106**, the desired amount and phase of concave-up H pincushion parabola to the V sawtooth modulator **110**. The resulting V scan sawtooth is modulated by the H pincushion parabola (column **3**) whereby the raster is taller toward the right and left sides thereof and narrower in the middle. Selection of the opposite phase of the H pincushion parabola provides a raster with shorter sides and a taller middle portion.

Referring now to FIG. **7**, an alternative embodiment of the hybrid video camera is depicted which includes the single pickup tube **18** and the two solid state image sensors **20, 24** for detecting red and blue color images. The sensors **20, 24** provide the red and blue color signal in response to the clock pulses thereto from the clock **35** as heretofore described. The tube **18** generates the luminance signal Y in response to the scan adjustment means **34**, and in synchronism with the sensor scan rate as coordinated by the sync generator **36**. The Y, R, B signals are fed to a gain/pedestal circuit **128** and thence to a gamma corrector circuit **130**. The processed luminance signal is fed, along with the processed R, B signals, to a low pass filter **132**, which is actually part of a matrix circuit **134**. The R and B signals are also fed to the low pass filter **132**. The G signal is obtained from the luminance signal by subtracting the R, B in given proportions therefrom. The low pass filter **132** attenuates the high frequency response of the luminance channel to match that of the red and blue channels from sensors **20, 24**. The matrix circuit **134** (and **132**) provides the color component signals R-Y and B-Y, which are fed to an encoder circuit **136**. The processed luminance signal from the gamma corrector circuit **130** is also fed to the encoder **136** via a high pass filter **137** which provides the luminance high-resolution components for the encoder without affecting the colorimetry, i.e., without the Livingstone's error of a four tube camera. The encoder generates the encoded composite video signal on output **32** in response to clocking via the sync generator **36**, as generally explained in FIGS. **1, 2**.

The additional components, e.g., the gain/pedestal, gamma corrector, matrix and encoder circuits **128–136** operate essentially in the manner described in the previous figures and in the pertinent references of previous mention.

FIG. **8** depicts a further embodiment of the hybrid video camera employing the single pickup tube **18** with a single solid state image sensor **138**. The tube generates the usual luminance signal which is fed to video processor means **140** formed of a preamplifier, gain/pedestal circuit and a gamma corrector circuit as in the previous embodiments. The sensor **138** is modified to include a striped filter **142** which is superimposed or otherwise placed over the sensor whereby; the first stripe is a red filter **144** and is disposed in register with a red photoelement **150** of the sensor; the second stripe is a green filter **146** disposed in register with a green photoelement **152**, and the third stripe is a blue filter **148** disposed in register with blue photoelement **154**. The sequence of the RGB filter stripes is repeated across the face of the sensor as depicted by RGB stripes **144', 146', 148'**, disposed in register with photoelements **150', 152', 154'**, respectively. The photoelements **150, 152, 154, 150', 152', 154'**, etc., are clocked at a selected scan rate commensurate with the scan rate of the tube **18** by the clock **35**, which in turn is coordinated by the sync generator **36**. The scanning is shown here as performed by an electronic clock stepping switch **156**. The RGB signals are sequentially fed to an electronic synchronous switch **158** via a preamplifier stage **160**. The switch **158** is stepped by the clock **35** in synchronism with the stepping of the clock stepping switch **156**, whereby the signals from the red photoelements **150, 150'**, etc., are fed to the red contact, the signals from the green photoelements **152, 152'**, etc., are fed to the green contact, and the signals from the blue photoelements **154, 154'**, etc., are fed to the blue contact, of the synchronous switch **158**. The RGB signals are fed via the switch **158** to the processor means **140** along with the luminance signals from the tube **18**. The processed signals are fed to a matrix circuit **162**, and thence as R-Y, B-Y to an encoder **164** along with the processed luminance signal, which encoder generates the encoded composite video output in response to synchronizing signals from the sync generator **36**. The scan adjustment means **34** provides the tube scan rate as well as the various scan correction waveforms for producing the near perfect tube scan raster of previous description.

I claim:

1. A hybrid television color camera including a lens and an optical prism for separating the luminance from selected chrominance components and for generating luminance and chrominance signals respectively therefrom, and further including video signal processing means for generating an encoded composite video color signal from the luminance and chrominance signals, comprising the combination of;

a single high-resolution pickup tube including an electron beam scan and a scan yoke and disposed to receive the luminance component of a given image and to generate a luminance signal of the order of 4.2 and greater megaHertz bandwidth;

low-resolution solid state sensor means having an array of sensor elements of near-perfect geometry, disposed in selected arrangement with the single pickup tube to receive the selected chrominance components of the same given image and to generate respective chrominance signals of bandwidths lower than that of the luminance signal;

scan adjustment means coupled to the scan yoke of the high-resolution tube to apply a correction waveform thereto to generate a near-perfect tube scan raster geometry which conforms to the near-perfect geometry of the sensor means; and

synchronizing means operatively coupled to the scan adjustment means and to the solid state sensor means for synchronizing the scan rate of the sensor means with the scan of the tube raster.

[redacted]

2. The hybrid camera of claim 1 wherein the scan adjustment means further includes;

waveform generator means for generating positive and negative waveforms which are mirror images of each other;

waveform modulator/adder means coupled to the waveform generator means for providing selected proportions and phase of the generated waveforms commensurate with the scan errors to modulate the amplitude of the deflection currents defining a composite precisely-corrected scan waveform; and

driver means coupled to the modulator/adder means for applying the precisely-corrected scan waveform to the tube scan yoke.

3. The hybrid camera of claim 1 wherein the synchronizing means further comprises;

a synchronizing signal generator for generating vertical and horizontal blanking pulses; and

clock means coupled to the solid state sensor means and responsive to the synchronizing signal generator to clock the sensor means at a scan rate commensurate with the scan rate of the single pickup tube.

4. The hybrid camera of claim 2 wherein the waveform generator means includes;

vertical and horizontal channels;

each channel including a sawtooth waveform generator responsive to the synchronizing signal generator, a parabola waveform generator coupled to the sawtooth waveform generator, and an ess waveform generator coupled to the parabola waveform generator; and

wherein the generators provide mirror image, positive and negative sawtooth, parabola and ess waveforms respectively.

5. The hybrid camera of claim 4 wherein the waveform modulator/adder means includes;

vertical and horizontal channels;

each channel including, a sawtooth waveform modulator selectively coupled to the waveform generators, and adder means coupled to the sawtooth waveform modulator respectively; and

said driver means being coupled to respective adder means in each channel and thence to the scan yoke of the pickup tube means.

6. The hybrid camera of claim 5 further including;

waveform adjust potentiometer means selectively coupled to each of the waveform generators in each channel thereof and including respective movable contacts which are adjustable to modify the amplitude and phase of the waveform generated by each generator commensurate with the degree of scan correction required.

7. The hybrid camera of claim 6 wherein the waveform adjust potentiometer means includes;

upright keystone adjust potentiometer coupled across the vertical sawtooth waveform generator; and

sideways keystone adjust potentiometer coupled across the horizontal sawtooth waveform generator.

8. The hybrid camera of claim 7 further including;

horizontal and vertical modulator means coupled to the upright and sideways keystone adjust potentiometers respectively;

horizontal and vertical adder amplifier means coupled to the horizontal and vertical modulator means respectively;

wherein upright keystone scan errors are corrected by modulating the horizontal sawtooth waveform from the horizontal sawtooth generator by a given amplitude and phase of the vertical sawtooth waveform commensurate with the upright keystone error as selected on the upright keystone adjust potentiometer, and adding the resulting waveform to the composite horizontal scan; and

sideways keystone scan errors are corrected by modulating the vertical sawtooth waveform from the vertical sawtooth generator by a given amplitude and phase of the horizontal sawtooth waveform commensurate with the sideways keystone error as selected on the sideways keystone adjust potentiometer, and adding the resulting waveform to the composite vertical scan.

9. The hybrid camera of claim 8 wherein the waveform adjust potentiometer means further includes;

vertical line bowing adjust and vertical pincushion adjust potentiometers coupled in parallel across the vertical parabola waveform generator; and

horizontal line bowing adjust and horizontal pincushion adjust potentiometers coupled in parallel across the horizontal parabola waveform generator.

10. The hybrid camera of claim 9 wherein;

said horizontal and vertical modulator means are coupled to the vertical and horizontal pincushion adjust potentiometers respectively;

wherein vertical pincushion scan errors are corrected by modulating the vertical sawtooth waveform from the vertical sawtooth generator by a given amplitude and phase of the horizontal parabola waveform commensurate with the horizontal pincushion error as selected on the horizontal pincushion adjust potentiometer, and adding the resulting waveform to the composite vertical scan; and

horizontal pincushion scan errors are corrected by modulating the horizontal sawtooth waveform from the horizontal sawtooth generator by a given amplitude and phase of the vertical parabola waveform commensurate with the vertical pincushion error as selected on the vertical pincushion adjust potentiometer, and adding the resulting waveform to the composite horizontal scan.

11. The hybrid camera of claim 9 wherein;

said horizontal and vertical adder amplitier means are also coupled to the vertical and horizontal line bowing adjust potentiometers respectively;

wherein vertical line bowing errors are corrected by adding a given amplitude and phase of the vertical parabola waveform commensurate with the vertical line bowing error as selected on the vertical line bowing adjust potentiometer, to the composite horizontal sawtooth waveform; and

horizontal line bowing errors are corrected by adding a given amplitude and phase of the horizontal parabola waveform commensurate with the horizontal line bowing error as selected on the horizontal line bowing adjust potentiometer, to the composite vertical sawtooth waveform.

12. The hybrid camera of claim 6 wherein the waveform adjust potentiometer means further includes;

vertical ess adjust potentiometer coupled across the vertical ess waveform generator; and

horizontal ess adjust potentiometer coupled across the horizontal ess waveform generator.

13. The hybrid camera of claim 12 wherein;

said horizontal and vertical adder amplifier means are also coupled to the horizontal and vertical ess adjust potentiometers respectively;

wherein vertical ess errors are corrected by adding a given amplitude and phase of the vertical ess waveform commensurate with the vertical ess error as selected on the vertical ess adjust potentiometer, to the composite vertical sawtooth waveform; and

the horizontal ess errors are corrected by adding a given amplitude and phase of the horizontal ess waveform commensurate with the horizontal ess error as selected on the horizontal ess adjust potentiometer, to the composite horizontal sawtooth waveform.

14. The hybrid camera of claim **12** wherein said waveform adjust potentiometer means further includes;

vertical linearity adjust potentiometer coupled across the vertical parabola waveform generator;

horizontal linearity adjust potentiometer coupled across the horizontal parabola waveform generator;

said horizontal and vertical adder amplifier means are also coupled to the horizontal and vertical linearity adjust potentiometers respectively;

wherein vertical linearity errors are corrected by adding a given amplitude and phase of the vertical parabola waveform commensurate with the vertical linearity errors as selected on the vertical linearity adjust potentiometer, to the composite vertical sawtooth waveform; and

the horizontal linearity errors are corrected by adding a given amplitude and phase of the horizontal parabola waveform commensurate with the horizontal linearity errors as selected on the horizontal linearity adjust potentiometer, to the composite horizontal sawtooth waveform.

15. The hybrid camera of claim **12** wherein said waveform adjust potentiometer means further includes;

horizontal skew adjust potentiometer coupled across the vertical sawtooth waveform generator;

vertical skew adjust potentiometer coupled across the horizontal sawtooth waveform generator;

said horizontal and vertical adder amplifier means are also coupled to the vertical and horizontal skew adjust potentiometers respectively;

wherein vertical skew errors are corrected by adding a given amplitude and phase of the horizontal sawtooth waveform commensurate with the vertical skew error as selected on the vertical skew adjust potentiometer, to the composite vertical sawtooth waveform; and

horizontal skew errors are corrected by adding a given amplitude and phase of the vertical sawtooth waveform commensurate with the horizontal skew error as selected on the horizontal skew adjust potentiometer, to the composite horizontal sawtooth waveform.

16. The hybrid camera of claim **3** wherein the solid state sensor means comprises;

red, green and blue solid state sensors disposed against the optical prism to receive therefrom the red, green and blue chrominance components, and to supply red, green and blue video signals to respective video processing means at a scan rate clocked by the clock means and commensurate with the scan rate of the pickup tube.

17. The hybrid camera of claim **16** wherein;

the sensors include a selected number of sensor elements in each horizontal row;

the sensors are clocked with a clock pulse rate which is 15,750 pulses per second times the number of sensor elements per row; and

wherein the first clock pulse for each row is referenced to the start of each tube scanning line.

18. The hybrid camera of claim **3** wherein the solid state sensor means comprises;

red and blue solid state sensors disposed against the optical prism to receive the red and blue chrominance components respectively, and to supply red and blue video signals to respective video processing means at a scan rate clocked by the clock means and commensurate with the scan rate of the pickup tube.

19. The hybrid camera of claim **3** wherein the solid state sensor means comprises;

a single solid state sensor disposed against the optical prism and including alternate red, green and blue photoelements;

red/green/blue filter means disposed between the prism and the sensor and including alternate red, green and blue filter stripes in register with respective red, green and blue photoelements of the sensor;

clock stepping switch means for sequentially clocking the red, green and blue photoelements in response to the clock means to generate consecutive series of red, green and blue video signals via the single sensor; and

synchronous color switch means coupled to the alternate red, green and blue photoelements and responsive to the clock means to direct the red, green and blue video signals to respective red, green and blue channels in the video processing means.

* * * * *

[redacted]

EXHIBIT 14

United States Patent [19]

Bayer

[11] **3,971,065**

[45] **July 20, 1976**

[54] **COLOR IMAGING ARRAY**

[75] Inventor: **Bryce E. Bayer**, Rochester, N.Y.

[73] Assignee: **Eastman Kodak Company**, Rochester, N.Y.

[22] Filed: **Mar. 5, 1975**

[21] Appl. No.: **555,477**

[52] **U.S. Cl.** ..... **358/41**; 350/162 SF; 350/317; 358/44

[51] **Int. Cl.²** **H04N 9/24**

[58] **Field of Search** ..... 358/44, 45, 46, 47, 358/48; 350/317, 162 SF; 315/169 TV

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Primary Examiner—George H. Libman

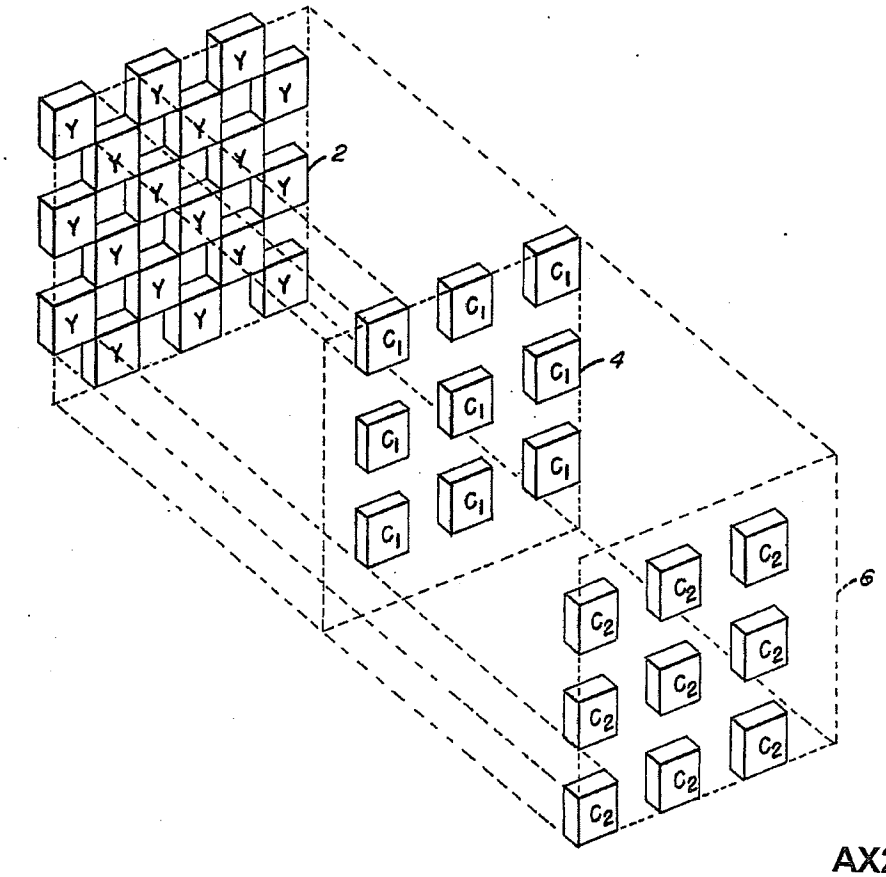
Attorney, Agent, or Firm—George E. Grosser

[57] **ABSTRACT**

A sensing array for color imaging includes individual luminance- and chrominance-sensitive elements that are so intermixed that each type of element (i.e., according to sensitivity characteristics) occurs in a repeated pattern with luminance elements dominating the array. Preferably, luminance elements occur at every other element position to provide a relatively high frequency sampling pattern which is uniform in two perpendicular directions (e.g., horizontal and vertical). The chrominance patterns are interlaid therewith and fill the remaining element positions to provide relatively lower frequencies of sampling.

In a presently preferred implementation, a mosaic of selectively transmissive filters is superposed in registration with a solid state imaging array having a broad range of light sensitivity, the distribution of filter types in the mosaic being in accordance with the above-described patterns.

11 Claims, 10 Drawing Figures



AX203354

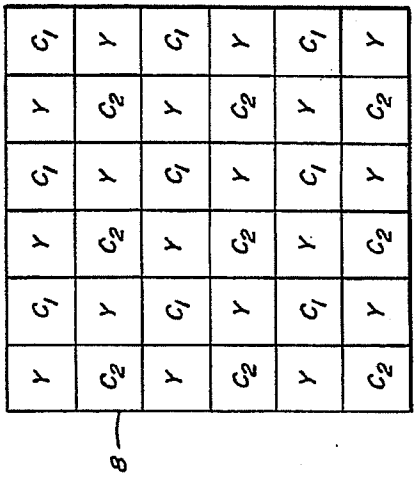


FIG. 1B

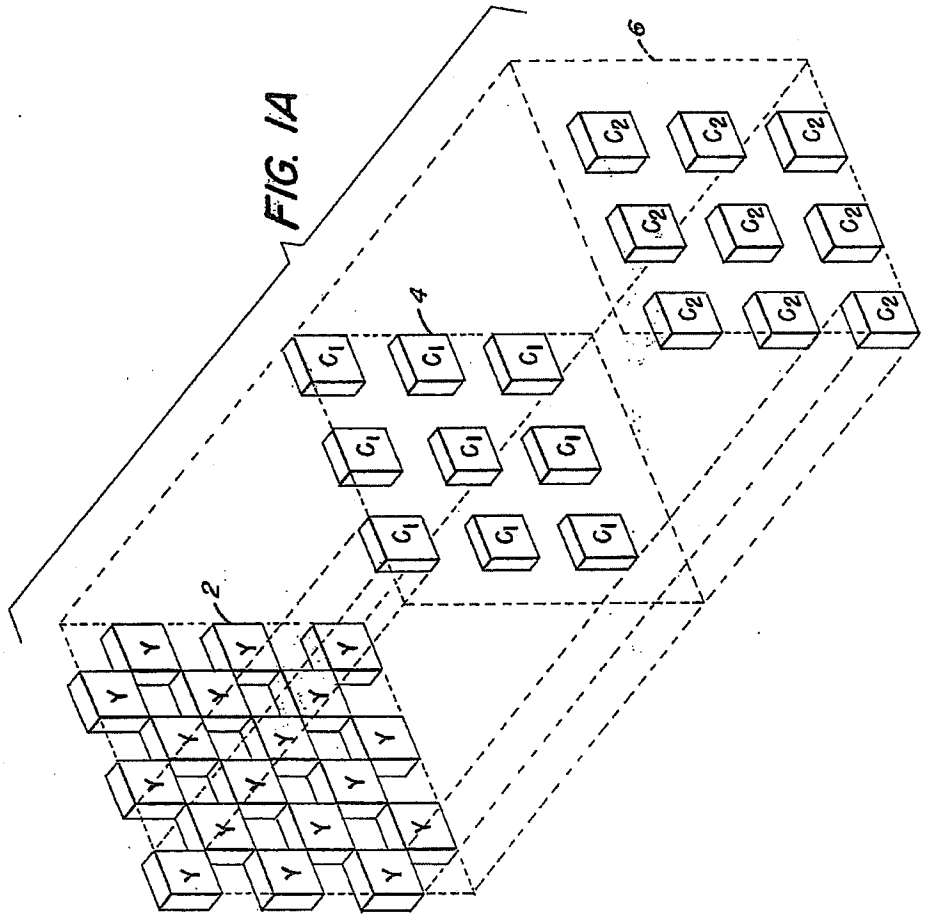


FIG. 1A

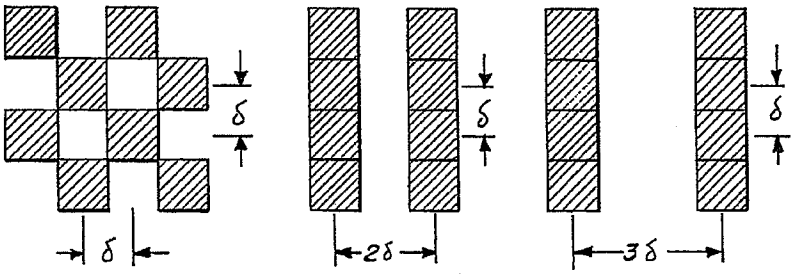


FIG. 2A FIG. 2B FIG. 2C

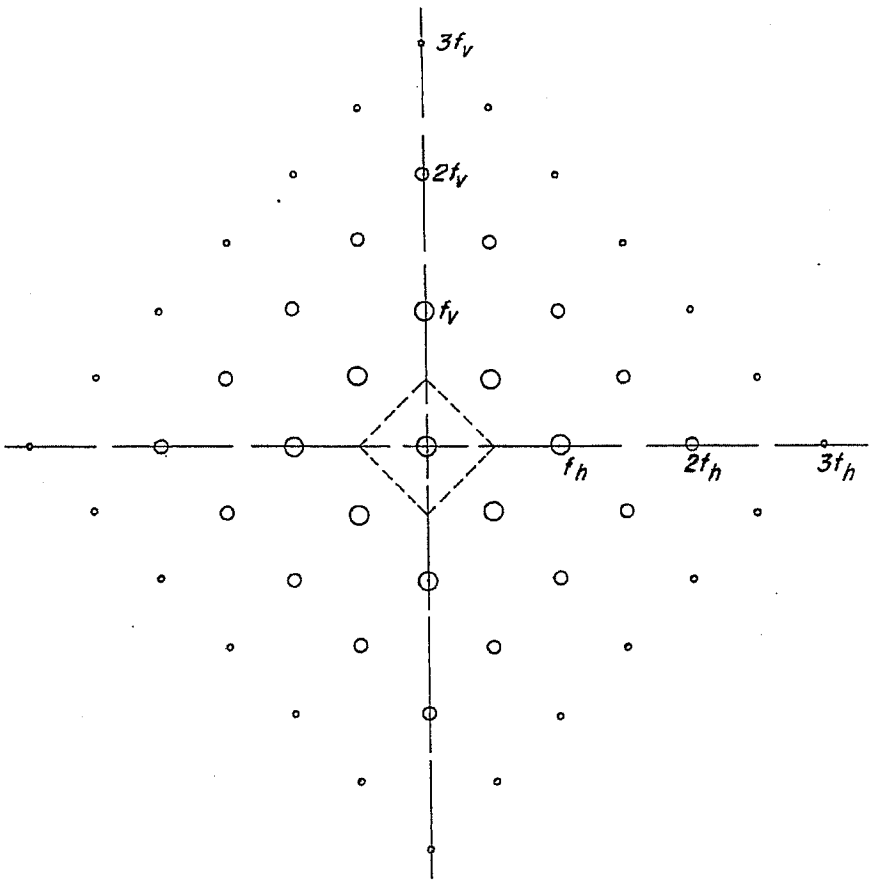


FIG. 2D

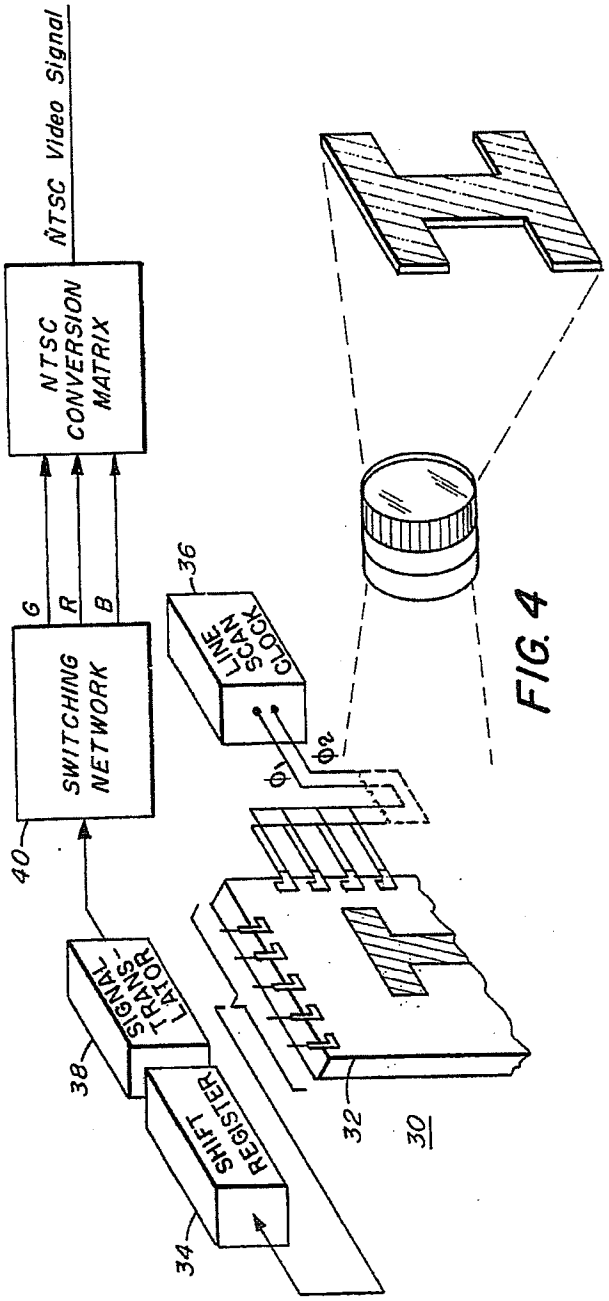


FIG. 4

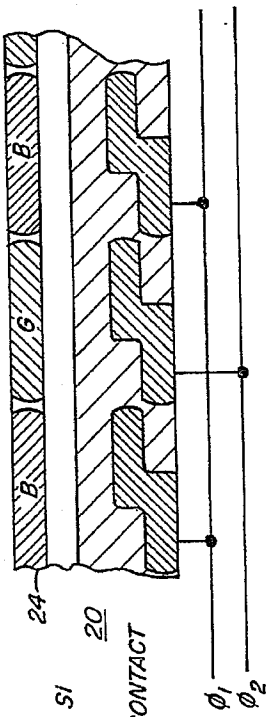


FIG. 3B

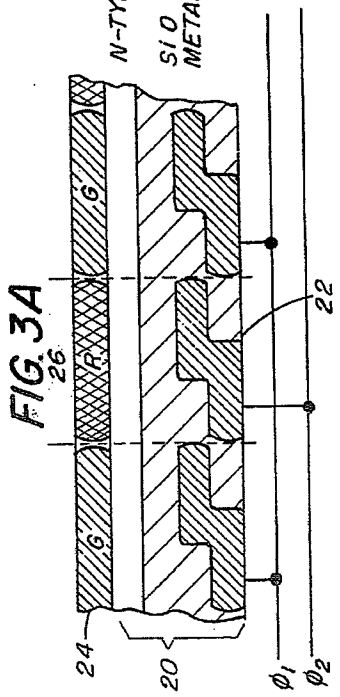


FIG. 3A

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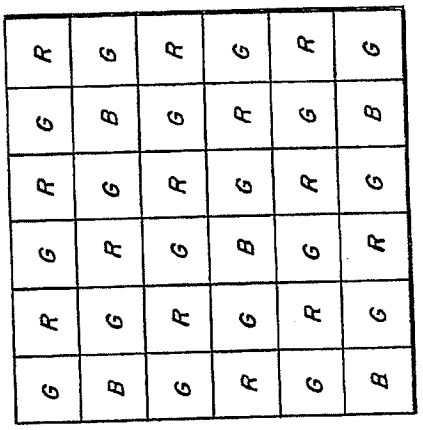

FIG. 6

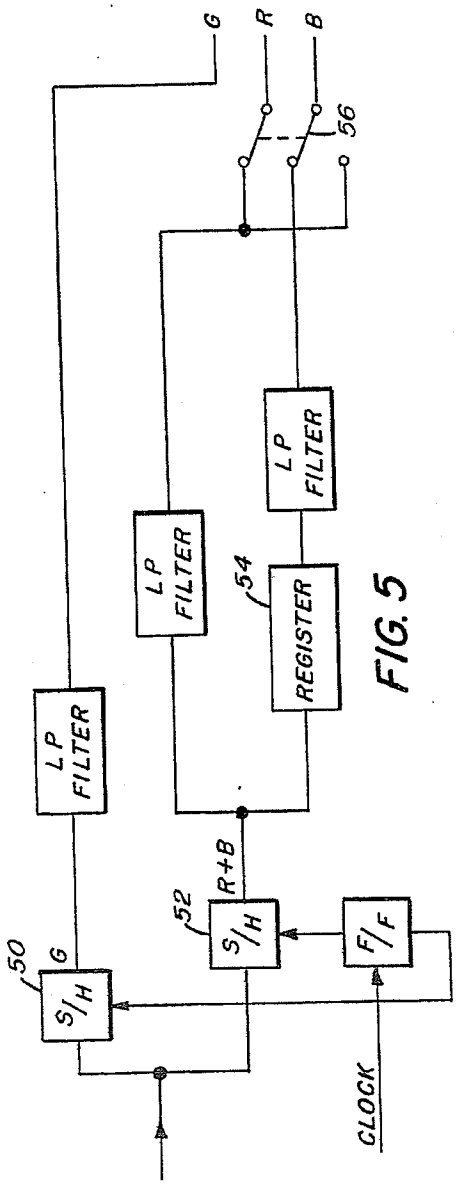

FIG. 5

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COLOR IMAGING ARRAY

BACKGROUND OF THE INVENTION

1. Field of the Invention

The invention relates to imaging devices and, in particular, to color image sensors.

2. Description Relative to the Prior Art

Color image sensors of various types have been proposed for and used in video cameras. To avoid optical complexity and problems with image registration, it is highly desirable that color image sensing occur at a single imaging site, e.g., at a single planar photosensitive array. Difficulty is encountered with such "single-site" color imaging, however, because at least three distinct types of color information must be extracted in order to represent a color image in video signal form.

One known approach to providing a single-site color sensing device utilizes a single image sensor of broad wavelength sensitivity and a cooperating filter disc which passes a series of color filters through the image beam in a repeating sequence. The filter interpositions are synchronized to image scanning, a filter typically being interposed during an entire field scan. Devices operating in this manner are said to produce a "field sequential" color signal. One problem with this approach is that the resulting signal presents the extracted color image information in a time order which is radically different from the time order of the standard NTSC video signal. A further disadvantage is that some of the color image information (e.g., blue image information if a blue basic color vector is utilized) tends to be disproportionately detailed and hence wasteful of sensor capacity in consideration of the response characteristics of the human visual system.

Certain other proposed approaches to achieving single-site color image sensing call for the use of striped color filters superposed on a single image sensor. One such type of image sensor utilizes filter grids which are angularly superimposed on one another (see U.S. Pat. No. 3,378,633). As a result of image scanning, such image sensors produce a composite signal wherein chrominance information is represented in the form of modulated carrier signals. Such apparatus may be adapted to produce signals in the NTSC format or, if desired, the color image information can be separated by frequency domain techniques. In practice, however, it has proven difficult to produce such sensors economically, particularly where detailed image information is required.

Striped filters which transmit a repeating sequence of three or more spectral bands have also been proposed for use in color imaging. With this arrangement, the filters are typically aligned vertically and scanning of the image is performed horizontally. In effect, elemental sample areas are defined along the filter stripes. With this arrangement, it will be appreciated, sampling for a given color is not uniform for horizontal and vertical directions. Additionally, the sampling patterns which result tend to provide a disproportionate quantity of information regarding basic color vectors to which the eye has less resolving power, e.g., "blue" information relative to "green" information.

Another approach to color imaging which has been proposed is the "dot" scanning system, as discussed in U.S. Pat. No. 2,683,769 to Banning. That approach generally utilizes spectrally selective sensor elements which are arranged in triads (red, green, and blue elements, respectively). However, in U.S. Pat. No. 2,755,334, also to Banning, a repeated arrangement of four element groupings (red-, green-, blue-, and white-sensitive elements, respectively) is described. Such approaches to color imaging have not been of practical significance, in part because of the cost of fabricating the number of individual elements which are required to provide image information having adequate detail.

In summary, while color imaging devices having a single imaging site are desirable to minimize optical and registration problems and to provide a more rugged camera structure, video camera manufacturers generally resort to splitting the image beam and providing multiple image scanners in order to achieve a satisfactory type and quality of color video signal.

SUMMARY OF THE INVENTION

Color imaging is effected by a single imaging array composed of individual luminance and chrominance sensing elements that are distributed according to type (sensitivity) in repeating interlaid patterns, the luminance pattern exhibiting the highest frequency of occurrence — and therefore the highest frequency of image sampling — irrespective of direction on the array.

In providing for a dominance of luminance sampling, recognition is taken of the human visual system's relatively greater ability to discern luminance detail. By arranging the luminance elements of the color image sensing array to occur at every other array position, a dominance of luminance elements is achieved in a pattern which has the special advantage of uniformity in two orthogonal directions (e.g., horizontal and vertical). Moreover, by so intermixing three types of elements (luminance, and first and second chrominance) that luminance elements occur at every other array position, and first and second chrominance elements alternate with such luminance elements in respective alternate rows of the array, there is provided a luminance-dominated sampling which is uniform for all three color vectors in two orthogonal directions. Certain desirable sampling attributes which result from the special uniformities of such arrangements are discussed in the detailed description below.

Preferably, to produce an element array according to the invention, a solid state sensor array of broad wavelength sensitivity is provided with a superposed filter mosaic. Filters of the mosaic are arranged in one-to-one registration with elements of the sensor array and have light passing characteristics in accordance with the above-described interlaid pattens. Filters which are selectively transparent in the green region of the spectrum are preferably employed in producing luminance-type elements, and filters which are selectively transparent in the red and blue spectral regions, respectively, are preferably employed in producing chrominance-type elements. (The term "luminance" is herein used in a broad sense to refer to the color vector which is the major contributor of luminance information. The term "chrominance" refers to those color vectors other than the luminance color vectors which provide a basis for defining an image.)

In an important alternative for implementation of the invention, three interlaid patterns, (a green-, a red-, and a blue-sensitive element pattern) are so arranged that green-sensitive elements (serving to detect luminance) occur at every other array position, with red-sensitive elements alternating with such green-sensitive

elements in alternate rows — as in the case for the presently preferred implementation. In the remaining element positions, however, blue-sensitive elements alternate with red-sensitive elements to produce a luminance-dominated image sampling having a disproportion in the chrominance samples favoring red over blue. With this arrangement, sampling rates for all three basic color vectors are adjusted respective of the acuity of the human visual system. That is, blue detail, to which the human visual has least resolution, is sampled the least frequently . . . green detail, to which the human visual system is most responsive, is sampled most frequently.

It will be appreciated from the foregoing that with selectively sensitized elements cooperating in interlaid sampling patterns according to the invention, image information is extracted with an efficient use of sensing elements because relative image sampling rates, by color, are in effect adjusted respective of the characteristics of human visual response. Moreover, with the uniformities of such interlaid sampling patterns, desirable sampling attributes are achieved for a plurality of sensing element types (color sensitivities) cooperating in a color imaging device.

The invention is described with reference to the drawings, wherein:

FIG. **1A** is an exploded pictorial representation showing preferred sensing element patterns for practicing the invention;

FIG. **1B** is a pictorial representaion corresponding to FIG. **1A**;

FIGS. **2A, 2B, 2C,** and **2D** are patten representations teaching a sampling characteristic of preferred forms of the invention;

FIG. **3A** is a cross-sectional representation, in part, of a row of sensing elements in accordance with a preferred implementation of the invention;

FIG. **3B** is a cross-sectional representation, in part, of a row of sensing elements adjacent the row represented in FIG. **3A**;

FIG. **4** is a perspective representation showing a basic arrangement of elements for a camera system according to the invention;

FIG. **5** is a diagrammatic representation generally in block form illustrating signal processing arrangements for use in conjunction with sensing arrays according to the invention; and

FIG. **6** is a planar view of another embodiment of the invention.

Referring now to FIGS. **1A** and **1B**, there is shown a set of three sensor patterns **2, 4,** and **6**, respectively, which are interlaid to form an image sampling array **8**, each such pattern corresponding to a different basic color vector. The pattern **2** (hereinafter referred to as the luminance pattern) has the highest element population, and is made up of luminance-sensitive elements (denoted Y), which are arranged at every other element position. With this pattern, it will be appreciated, luminance elements (and hence luminance samples) occur at half of the element positions of the array and are uniformly distributed over the entire array. First and second chrominance patterns **4** and **6** alternate with the luminance pattern in alternate rows, respectively, to provide a composite sampling array devoid of overlapping. As a result of this arrangement, sampling of an image, for all three basic color vectors (i.e., luminance, first and second chrominance), is symmetrical and uniform in two orthogonal directions (e.g., horizontal and vertical), as is readily seen from FIG. **1B**.

FIGS. **2A, 2B,** and **2C** illustrate the advance over certain prior art by means of the invention. Referring to FIGS. **2A, 2B,** and **2C**, the distance between rows of elements in the horizontal and vertical directions is shown for the luminance pattern **2** (FIG. **1A**), and for prior art striped element patterns (e.g., as would exist where a vertically striped filter is superposed on a sensor array). Luminance pattern **2** (FIG. **2A**) is seen to provide uniform sampling in the horizontal and vertical directions, whereas the striped patterns of FIGS. **2B** and **2C** do not. (Note: FIG. **2B** shows a striped arrangement having a numerically similar luminance element population, and FIG. **2C** shows a striped filter of the type having alternating stripes for each of three basic color vectors.) For each row and column of elements, the FIG. **2A** luminance elements (and hence luminance samples) occur at regular intervals. Moreover, by means of the invention, not only the luminance pattern, but all other patterns (**4** and **6**, FIG. **1A**) of a sensor according to the invention become regular and uniform in two orthogonal directions.

The preferred luminance pattern as especially desirable sampling qualities which result from the uniformity and orientation thereof. Of the possible patterns including only half of the element positions of a substantially rectangular array, the preferred pattern is the one that affords the largest useful region of frequency space, i.e., considering all directions on the array, the minimum Nyquist limit is largest. Moreover, because of the orientation of the preferred pattern to the major axes, this usable region proves more extensive in the horizontal and vertical directions . . . those directions where the human visual system is said to have greatest resolving power.

To further explain these sampling qualities, reference is made to FIG. **2D**, where the sampling frequencies and harmonics for the preferred luminance patten are graphically illustrated in frequency space. By virtue of uniformity of the preferred luminance sampling pattern, the horizontal and vertical sampling rates are equal. The Nyquist or usable frequency region, i.e., the region including frequencies closer to the origin than to the sampling frequencies, is located in a substantially square portion of the frequency space (indicated by a dashed line) having its diagonals aligned with the horizontal and vertical directions (hence extending further in those directions).

Referring now to FIGS. **3A** and **3B**, a preferred imaging apparatus for implementing the invention employs a solid state imaging array **20** of the CCD type comprised of individual sensor elements (e.g., element **22** extending between the dashed lines of FIG. **3A**). A filter mosaic **24** is superposed on imaging array **20**, which mosaic includes individual filters (e.g., filter **26**) in one-to-one registration with individual sensor elements of the array (e.g., the element **22**). Individual filters of mosaic **24**, forming a filter mosaic over the array **20**, are of the selectively transmitting type, and are arranged in patterns as described above. The letters G, R, B on individual filters of mosaic **24** (FIGS. **3A** and **3B**) serve to indicate green, red, and blue light transmission characteristics, respectively, as would be employed according to the presently preferred form of the invention. Filters selectively transmissive to light in the green region of the spectrum are utilized in producing luminance-sensitive elements, and red and blue

transmitting filters are used for producing first and second chrominance-sensitive elements.

A selectively sensitive, color imaging element, such as element **26**, is formed by each one of filters **24** in combination with a corresponding array sensor (for element **26** the sensor denoted **22**). It will be appreciated, however, that an array according to the invention might also be formed of sensors having selective wavelength sensitivity; or by use of lenticular filters separate from an array of sensor elements, which filters selectively limit the wavelengths of light arriving at individual elements of such array.

Referring to FIG. **4**, a color imaging array **30** according to the invention is shown in a simplified camera environment. Image information from individual rows of the array, such as a row **32**, is transferred to a shift register **34** (generally formed "on board" the imaging chip) in response to signals from an interrogating apparatus such as a line scan clock **36**. Such operation is well known, and apparatus for performing same is described in literature and patents regarding CCD arrays. It is also generally known to process the output signal of the register by means of a circuit **38**. Using color imaging arrays according to the invention, however, information for the various base color vectors is interspersed as a result of the intermixed sensitivities of the color array elements. Accordingly, a switching network **40** is provided to separate the image signal sequence to a usable form, for example, to parallel green, red, and blue video signals.

In such form, the signals are conveniently converted to NTSC format using a conversion matrix of **2**. This is especially convenient if the number of rows in the array corresponds to the number of visible lines in a field scan (approximately 250) or the number of visible lines in a frame (approximately 500) comprised of interlaced fields.

A simplified diagram for a switching network **30** is shown in FIG. **5**. Sample and hold units **50** and **52** are employed in alternating operation to separate out, respectively, green information and the chrominance information. The latter alternates between red and blue with each successive row of the array. Since red information and blue information is received on an alternating row basis, such information is stored in a register **54** for an entire row and shifted out serially as the next row's luminance information arrives.

To maintain the same output channels for red information and blue information, irrespective of row, switching means **56** alternates the output connection from the register with each row of output information.

An important alternative set of patterns for implementing color imaging arrays according to the invention is shown in FIG. **6**. The luminance (green) pattern, having elements denoted by a "G", assumes every other array position. A red pattern, having elements denoted by an "R", alternates with luminance elements (denoted "B") in alternate rows, and red elements also alternate with blue elements in filling the remaining element positions. By this arrangement, blue elements contribute only one-eighth of the element population . . . a recognition of the human visual system's relatively limited ability to discern blue detail. Red detail, to which the human visual system is more responsive, is sampled at a higher rate than for blue detail by virtue of the relatively greater population of red-sensitive elements. Luminance detail, to which the human eye is most responsive, is sampled by the largest population of elements. Through this arrangement, image sampling is coordinated to closely match the response of the human visual system; however, it will be appreciated that separating and storing red and blue image information becomes more complicated when the red and blue patterns differ.

The invention has been described in detail with particular respect to implementations thereof, but it will be appreciated that variations and modifications can be effected within the spirit and scope of the invention. For example, a variety of sensors might be employed, including the sensors of CCD or CID imaging arrays. Moreover, color-sensitive elements for use in the invention may have inherent selective sensitivity or may incorporate filters either adjacent to or removed from a broad-wavelength-range sensor, which filters selectively limit the range of sensitivity for individual sensors. Also, while the invention is cast in the environment of a camera utilization, it has other uses, for example, in connection with a display device.

What is claimed is:

1. A color imaging device comprising an array of light-sensitive elements, which array includes at least (1) a first type of element sensitive to a spectral region corresponding to luminance, (2) a second type of element sensitive to one spectral region corresponding to chrominance, and (3) a third type of element sensitive to a different spectral region corresponding to chrominance, the three types of elements occurring in repeating patterns which are such that over at least a major portion of said array luminance-type elements occur at every other element position along both of two orthogonal directions of said array.

2. A device in accordance with claim **1** wherein said luminance-type elements are sensitive in the green region of the spectrum, and the two types of chrominance elements are sensitive in the red and blue regions of the spectrum, respectively.

3. An array in accordance with claim **1** wherein the elements are arranged in a substantially rectangular pattern and the two chrominance types of sensors alternate with the luminance sensors in alternate rows, respectively, of the rectangular pattern.

4. A color image sensor comprising:

a. a substantially planar array of solid state light-sensitive elements; and

b. a filter mosaic made up of individual filter elements which are superposed in one-to-one registry on said light-sensitive elements, said mosaic being comprised of a first type of filter element having a luminance transparency characteristic, a second type of filter element having a transparency characteristic different from that of said first type, and a third type of filter element having a transparency characteristic different from that of said first and second types, such filter elements being arranged in repeating patterns respective of type with the luminance filters occurring at every other array position in two perpendicular directions throughout substantially the entire imaging area of the sensor.

5. A sensor according to claim **4** wherein the first type filters are arranged at every other array position, and said second and third type filters alternate with the first type filters in respective alternate rows of the array.

6. A sensor according to claim **4** wherein the first type filters occur at every other array position, and the

third type filters occur in alternate rows at every fourth position, the second type filters occurring at all remaining positions, whereby a hierarchy of distributed sampling populations is provided.

7. A sensor according to claim 6 wherein the first type of filter transmits for the green spectral range, the second type of filter transmits for the red spectral range, and the third type of filter transmits for the blue spectral range.

8. A video image sensor comprising a first type of element sensitive to a luminance region of the spectrum, and a second and a third type of element sensitive to respective different chrominance regions of the spectrum, said sensor, over substantially the entire imaging area thereof, having such elements arranged as a mosaic of individual groups of four neighboring elements in a generally square configuration, which groups each include two diagonally-arranged first-type elements, one second-type element, and one third-type element.

9. A video image sensor according to claim 8 wherein said first-type elements within the individual groups are aligned in a common diagonal direction.

10. A video image sensor according to claim 9 wherein said first-type element is sensitive to the green region of the spectrum, the second-type element is sensitive to the red region of the spectrum, and the third-type element is sensitive to the blue region of the spectrum.

11. An image sensor according to claim 8 wherein individual first-, second-, and third-type elements are comprised of a broad spectrum photoresponsive device with a spectrally selective filter superposed in registry therewith.

* * * * *

UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

PATENT NO. : 3,971,065
DATED : July 20, 1976
INVENTOR(S) : Bryce E. Bayer

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 5, lines 56-60: Change sentence to read: --A red pattern, having elements denoted by an "R", alternates with blue elements (denoted "B") in alternate rows, and red elements fill the remaining element positions.--

Signed and Sealed this

Fifth Day of *September 1978*

[SEAL]

Attest:

RUTH C. MASON
Attesting Officer

DONALD W. BANNER
Commissioner of Patents and Trademarks

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